Proximity to coarse woody debris increases reptile presence in an Australian subtropical rainforest remnant

Melanie McGregor[A,C], Scott Burnett[B]

[A]Environmental Futures Research Institute, Griffith University, Nathan QLD 4111, Australia.

[B]School of Science and Education, University of the Sunshine Coast, Maroochydore QLD 4558, Australia.

[C]Corresponding author
Environmental Futures Research Institute, Griffith University, Nathan QLD 4111, Australia
Email: mel.mcgregor@griffithuni.edu.au

ABSTRACT

The persistence of Australia's forest herpetofauna communities depends on the availability of spatially heterogeneous microhabitats. The composition of these communities is directly related to the availability of complex structures such as coarse woody debris, an integral attribute of forest ecosystems that provides structurally diverse habitat for biota. This study aimed to determine whether the distribution of herpetofauna within an Australian subtropical rainforest remnant is significantly influenced by the presence or absence of coarse woody debris. Capture and release of herpetofauna at 30 sample sites (15 with coarse woody debris present within a 20 m proximity and 15 with coarse woody debris absent within a 20 m proximity) using double-ended funnel traps determined that reptile capture frequencies were significantly higher at sites with coarse woody debris, due mainly to large captures of *Eulamprus murrayi*. Amphibian capture frequencies did not differ between the two site types, but was found to differ with rainfall events. Findings from this study suggest that management practices reducing coarse woody debris availability should be avoided.

Key words: coarse woody debris, herpetofauna, subtropical, rainforest, southeast Queensland.

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Introduction

Coarse woody debris (CWD), which includes part or whole standing or fallen dead trees, logs, branches and large roots, plays a key role in many ecological functions (Harmon et al. 1986; Woldendorp et al. 2002; Woldendorp and Keenan 2005). Among these functions, the retention of moisture and temperature stability associated with CWD provides microhabitat for plants, fungi and invertebrates (Stevens 1997; Browning et al. 2010; Castro and Wise 2010; Gates et al. 2011). These unique microhabitat characteristics also make CWD important to many vertebrate species (Bowman et al. 2001; Kanowski et al. 2006; Mac Nally and Horrocks 2007).

Herpetofauna frequently integrate CWD into a range of behavioural and physiological aspects of their ecology (Harmon et al. 1986; Whiles and Grubaugh 1996; Webb and Shine 1998; Riffell et al. 2011). Some reptile species have been shown to exhibit a close association with CWD in Australian woodlands (Sarre 1998; Brown 2001) and rainforests (Kanowski et al. 2006). Such associations have also been documented in other parts of the world, particularly in the United States of America (Whiles and Grubaugh 1996; Crosswhite et al. 2004; Owens et al. 2008; Todd and Andrews 2008). Some studies have also observed a significant relationship between the presence of CWD and the abundance of amphibians (Aubry et al. 1988; Butts and McComb 2000; Pilliod et al. 2003; Patrick et al. 2006). Other studies have, however, observed no significant relationship between these factors, predominantly in North America (Aubry 2000; Owens et al. 2008), but also in Australia (Mac Nally et al. 2001).

Despite recent research, herpetofauna are still regarded as the least researched group in relation to CWD (Harmon et al. 1986; Riffell et al. 2011). Further exploration of this relationship will provide a greater understanding of the distribution and abundance of such species and associated ecological mechanisms. This is vital to ecological management (Watling 2005), especially for those species already spatially restricted or endangered. This study aimed to explore the potential variation in herpetofauna communities in relation to proximity to CWD within an Australian subtropical rainforest remnant.

Methods

Study area

This study was undertaken within the Mary Cairncross Scenic Reserve (26° 46' 41.96" S, 152° 52' 49.78" E), comprising 55 ha of remnant subtropical old growth rainforest. Mary Cairncross Scenic Reserve is located on the Maleny Plateau in the Sunshine Coast hinterland of southern Queensland. The climate of the plateau is subtropical (Köppen Classification: Australian Bureau of Meteorology 2011), with mild seasonal temperatures. Mean annual rainfall of the area is approximately 1988 mm, falling primarily during the December to April wet season (Australian Bureau of Meteorology 2011).

The study area comprises three distinct vegetation communities, largely dominated by white booyong (*Argyrodendron trifoliatum*), native black bean (*Castanospermum australe*) and piccabeen palm (*Archontophoenix cunninghamiana*) and an understorey of fern and sedge species (Smyrell 2007). Herpetofauna identified in the study area comprises 34 reptile species and 17 amphibian species. These include rare or endangered Stephen's banded snake (*Hoplocephalus stephensii*), three-toed snake-tooth skink (*Coeranoscincus reticulatus*), short-limbed snake skink (*Ophioscincus truncatus*), elf skink (*Eroticoscincus graciloides*) and tusked frog (*Adelotus brevis*).

Site selection

This study used paired (topographically similar) CWD and non-CWD sites to investigate whether a relationship exists between herpetofauna distributions within the study area and the occurrence of CWD. Sampling occurred at 30 sites over a two month period (Figure 1). Fifteen of the sampling sites were non-CWD sites, in which traps were located greater than 20 m from CWD that was considered significant herpetofauna habitat (fallen, in full contact with the ground and over 20 cm diameter). This measurement was based on the assumption that most herpetofauna have small home ranges (Ross et al. 2000; Chambers 2002) and that a separation of 20 m would be sufficient to class the site as 'non-CWD'. The remaining 15 sampling sites were CWD sites, focussed around a substantial piece of CWD. Sampling sites were primarily positioned at least 50 m apart to ensure independence.

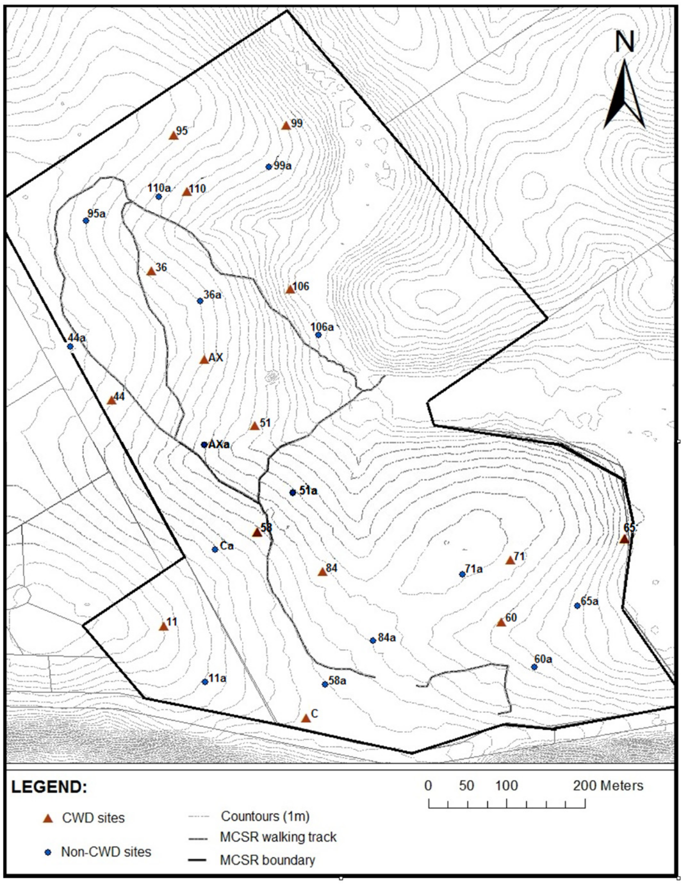

Figure 1. Thirty herpetofauna trapping sites sampled within Mary Cairncross Scenic Reserve during the study. Paired non-CWD/CWD sites are denoted by the same identification tag, with non-CWD sites labelled with an 'a') (Map data supplied by the Sunshine Coast Regional Council).

From 160 identified CWD sites, 15 sample sites were chosen based on size (greater than 10 m in length) and an advanced state of decay; important parameters for CWD to be classified as suitable vertebrate habitat (Raphael and White 1984; Goodburn and Lorimer 1998). Fifteen corresponding non-CWD sites were then selected based on similarity in vegetation type, aspect, elevation and canopy light penetration to a paired CWD site. This was done to provide environmental consistency between non-CWD and CWD sites, which increased the likelihood that any variation of herpetofauna communities was due to variation in CWD as the principle influence.

Site parameters (collectively referred to as 'site composition') were measured in order to determine similarity between sampling sites such that the role of CWD, as the primary difference between sites, could be quantified. Sample site parameters were measured within a 5 m radius around each trap array (total site size: 10 x 16 m). Leaf litter depth and quantitative counts (percent cover, number) of resources within the sampling site (ground cover, stags, hollows, strangler figs, rocks, logs, brush-turkey (Alectura lathami) mounds, vines, bare soil, palm fronds and small woody debris) were recorded. At each CWD site a soil penetrometer (10 mm plunger) was used to take six hardness readings of the sampling site log (kg/cm^2) at 1 m intervals for the length of the trap array. Vegetation structure was also recorded (percent crown and undergrowth covers, maximum canopy height and dominant species).

Herpetofauna sampling

Herpetofauna capture at each sampling site was performed through the use of a single live-trapping array (Figure 2). Each trap array consisted of a 6 m length of 70 cm high aluminium flywire drift fence, buried 5 cm into the ground, alongside which three pairs of double-ended herpetofauna funnel traps (Coast to Coast Vermin Traps, Baldivis, Western Australia) were placed. This sampling technique has been considered successful in sampling surface active and fossorial herpetofauna (Greenberg et al. 1994; Crosswhite et al. 1999) in the study area (Burnett and Bright 2009). Herpetofauna sampling occurred during December 2010 and January 2011. Eight paired sites were sampled simultaneously for five days, except in the final week when six sites were sampled.

At each CWD site, an array was placed parallel to the site log. At each non-CWD site, an array was placed as far away from any small woody debris as possible and more than 20 m from any CWD (Figure 2). Each trap was checked morning and afternoon, with captured herpetofauna identified to species level and typical morphological measurements recorded before release. Each individual was photographed for individual patterning which, in combination with morphological measurements, provided a reliable basis for identifying recaptures.

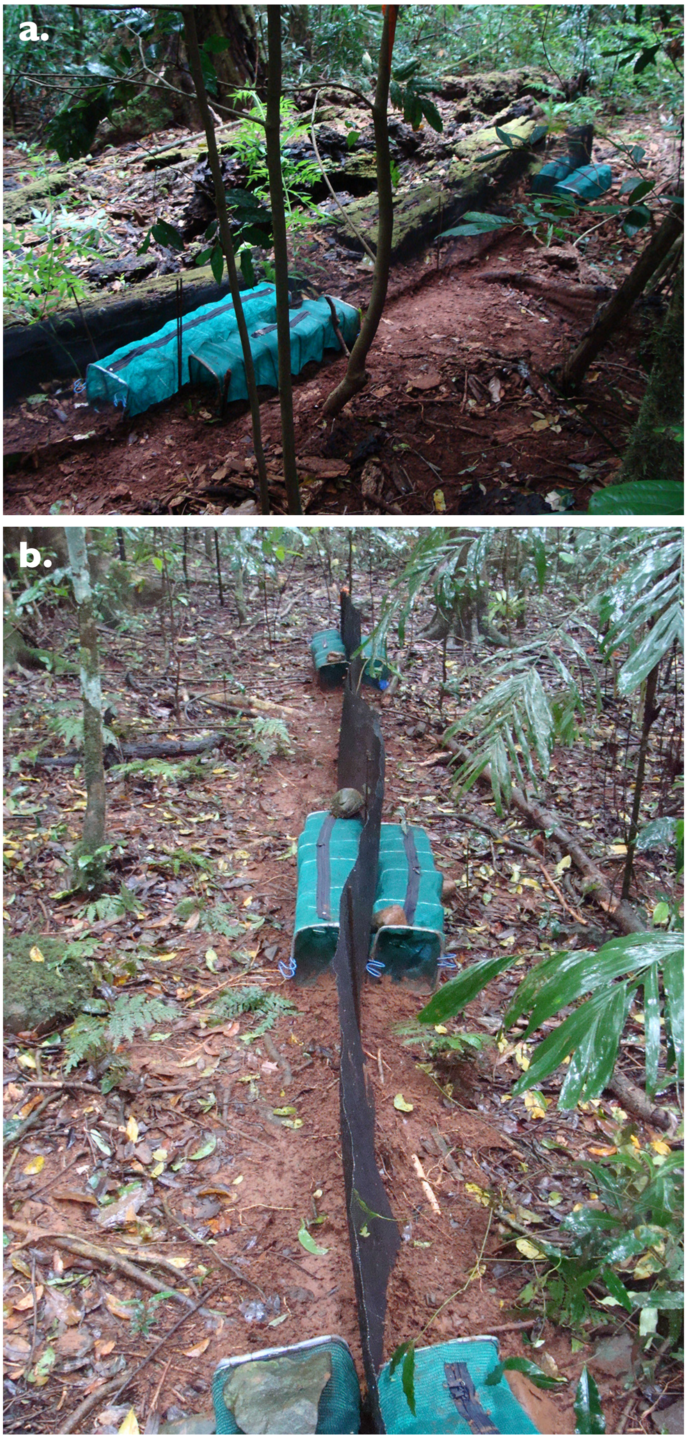

Figure 2. Typical layout of a CWD sampling site (a) and a non-CWD sampling sites (b) (photos: M. McGregor)

Data analysis

Herpetofauna captures

To determine statistical significance between the capture frequencies at CWD and non-CWD sites, three analysis of variance (ANOVA) tests were performed using SPSS (Version 19, IBM). ANOVAs were performed on total herpetofauna captures, reptile captures only, and amphibian captures only. Reptile capture data were normalised using a square root transformation and amphibian data were not transformed. Significance in E. murrayi captures between a priori groups was determined using a Mann Whitney U independent samples test. All tests were run at a significance level of 0.05.

Rainfall throughout the sampling period was extremely high, with 1270 mm recorded in Maleny from 1 December 2010 to 20 January 2011, with 600 mm recorded over three days (January 10 - 13) (Australian Bureau of Meteorology 2011). Due to this unusually high rainfall, reptile and amphibian capture frequencies were compared with recorded rainfall, categorised into 'low' (0 to 1.8 mm), 'moderate' (5.2 to 21.0 mm) and 'heavy' (38.4 to 282.6 mm) rainfall to allow Spearman's Rank analysis.

Sampling site similarity

To determine similarity between sampling sites, resemblance matrices were constructed for composition and species captures prior to univariate and multivariate analysis (PRIMER Version 6, PRIMER-E Ltd). Site composition analysis was based on a resemblance matrix calculated using Euclidean distances between sampling sites, while species captures resemblance used Bray-Curtis similarity (Faith et al. 1991). Combinations of the following tests were used to determine sampling site similarity, as well as to confirm that the presence or absence of CWD was a determining factor of dissimilarity between a priori groups.

Analysis of similarity (ANOSIM) was used to determine statistical similarity between CWD and non-CWD sites. Following this, the contribution of each site composition variable to within-group similarity, and between-group dissimilarity, with regard to the a priori groups was examined using single factor SIMPER analysis (Euclidean distance). Non-metric multidimensional scaling (MDS) analysis using a Euclidean distance similarity matrix was conducted on standardised habitat composition data to provide visual representation of site composition similarity.

Log characteristics

Non-metric MDS analysis, using Euclidean distance, was performed to determine similarity between the site logs at each of the 15 CWD sites. A BIOENV analysis was then used to explore which log parameters, if any, best explained herpetofauna assemblage patterns. Mean log hardness was also tested independently, using ranked hardness categories to allow Spearman's Rank analysis between herpetofauna, reptile and amphibian capture frequencies. Eulamprus murrayi captures were also tested separately, due to high capture rates.

Results

Herpetofauna captures

Seventy-eight individual herptiles belonging to 10 species were captured during this study. These included 49 reptiles, comprising five lizard species and two snake species, and 29 amphibians, comprising three frog species (Table 1). The highest number of captures at any sampling site was eight individuals and the highest species richness at any one site was four species. Thirty-seven *E. murrayi* were caught throughout the sampling period, occurring at 15 of the 30 sampling sites (47.4% of total captures). Conversely, only one capture was made of *Hypsilurus spinipes, Lampropholis delicata, Coeranoscincus reticulatus* and *Cacophis krefftii*. Herpetofauna captures were made at all 15 CWD sites, compared with six (40%) of the non-CWD sites.

Means of total herpetofauna captures (ANOVA: F1,28 = 6.12, P = 0.020) and reptile only captures (ANOVA: F1,28 = 15.5, P = 0.000) were higher at CWD sites than at non-CWD sites. When *E. murrayi* captures were removed, reptile capture frequencies were equal, with six captures at CWD and non-CWD sites. *Eulamprus murrayi* captures were significantly different between CWD and non CWD sites (Mann Whitney: U=26.5, p<0.001) with the majority of captures occurring at CWD sites. There was no significant difference in the mean number of amphibian captures between CWD and non-CWD sites (ANOVA: F1,28 = 0.19, P = 0.891). Spearman's Rank correlations determined moderate, significant positive correlation between amphibian capture frequencies and categorised rainfall (r = 0.524, P = 0.015) and a moderate, significant negative correlation between reptile capture frequencies and categorised rainfall (r = -0.531, P = 0.013).

Table 1. Reptile and amphibian species captured in Mary Cairncross Scenic Reserve during this study (December 2010 and January 2011).

Species	% of total captures	Captures CWD	Captures non CWD
Reptiles			
Eulamprus murrayi (Murray's skink)	47.4	34	3
Calyptotis lepidorostrum (cone-eared Calyptotis)	5.1	3	1
Coeranoscincus reticulatus (three-toed snake-toothed skink)	1.3	1	0
Lampropholis delicata (garden skink)	1.3	0	1
Ramphotyphlops nigrescens (blind snake)	5.1	2	2
Cacophis krefftii (dwarf crowned snake)	1.3	0	1
Hypsilurus spinipes (southern angle-headed dragon)	1.3	0	1
Amphibians			
Adelotus brevis (tusked frog)	6.4	3	2
Limnodynastes peronii (striped marshfrog)	6.4	3	2
Mixophyes fasciolatus (great barred frog)	24.4	8	11
TOTAL	**100.0**	**54**	**24**

Sampling site similarity

When CWD variables 'logs' and 'log piles' were removed from the data set, MDS analysis demonstrated little dissimilarity between CWD and non-CWD sites. Expectedly, the MDS plot shows most paired sampling sites close together (Figure 3). ANOSIM analysis performed between the a priori groups (CWD variables removed) using a resemblance matrix (calculated from composition data) found no significant variation between CWD sites and non-CWD sites (R = -0.022, sig. 0.652)

With the CWD variables returned to the data set, a second MDS illustrates a similar scatter of distance between sampling sites but with a clear separation of CWD sites and non-CWD sites (Figure 4). Likewise, ANOSIM analysis performed between the a priori groups (CWD variables included) demonstrates a significant difference between CWD and non-CWD site composition (R = 0.383, sig. 0.001)

Following the MDS and ANOSIM analyses, a SIMPER analysis using Euclidean distance determined an overall similarity within sampling site types (CWD variables

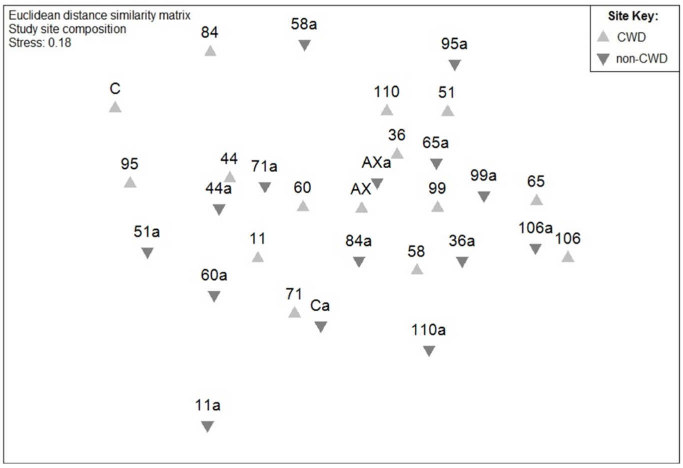

Figure 3. MDS representation showing dimensional spacing between all study sites when CWD variables are not included (Paired sites are indicated by the same site name, with the addition of 'a' denoting the non-CWD site).

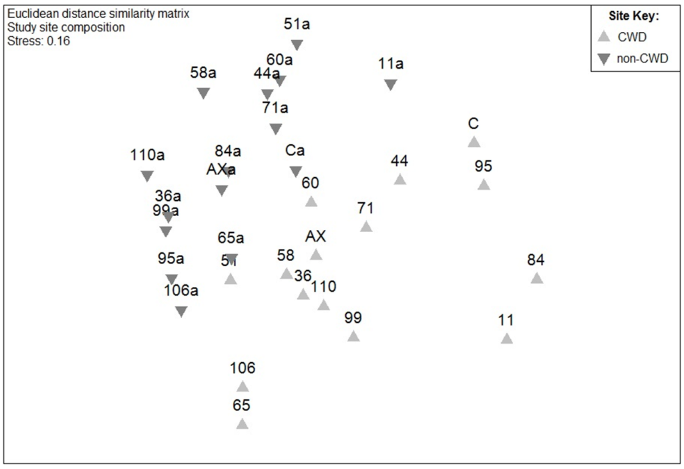

Figure 4. MDS representation showing dimensional spacing between all 30 study sites when CWD variables are included (Paired sites are indicated by the same site name, with the addition of 'a' denoting the non-CWD site)

included). Both CWD and non-CWD sites were determined to be relatively similar in composition, with average squared distance among CWD sites (6.79) and among non-CWD sites (5.86) being relatively low. The SIMPER test also determined that palm fronds contributed most to average squared distance within CWD and non-CWD sites respectively (Table 2).

The SIMPER test found the dissimilarity between CWD and non-CWD sites to be much greater than within group dissimilarities, with averaged squared distance being 16.39 - almost three times the distance observed within groups. These results were largely due to the two CWD variables, with a combined distance contribution of 33.97% (Table 3).

Log similarity

MDS analysis determined dissimilarity between most of the sampling site logs. Based on the four measured variables of diameter, length, useful length and mean hardness (kg/cm^2) of each of the sampling site logs, two clusters were evident, with one outlier present (site log 65). BIOENV analysis (Spearman), matching the herpetofauna captures resemblance matrix (Bray-Curtis) against the matrix of sampling site log measurements, did not produce any significant correlations with any combination of variables. The highest correlation, though still very low, was produced when all four variables were run ($r = 0.180$).

No significant correlation was identified between log hardness and total herpetofauna, reptile captures or amphibian captures when Spearman's Rank correlation analysis was performed to test this relationship separately. The most closely correlated was the four category grouping, though results for reptile captures ($r = 0.43$, $P = 0.11$), amphibian captures ($r = 0.32$, $P = 0.25$) and total herpetofauna captures ($r = 0.47$, $P = 0.08$) were still not significant. Spearman's Rank correlation analysis performed between capture frequencies of *E. murrayi* and categorised log hardness data also showed no significance in five ($r = 0.38$, $P = 0.17$), four ($r = 0.38$, $P = 0.16$), or three ($r = 0.34$, $P = 0.22$) hardness categories.

Discussion

Herpetofauna captures

Reptile capture frequencies in this study were significantly higher at sampling sites with CWD while those for amphibians did not differ between the CWD and non-CWD sites (Table 1). The significantly higher capture frequencies of reptiles was due to the high number of captures of E. murrayi, which contributed 82% of total reptile captures, and which is known to have a strong relationship with CWD (Wilson 2009). Eulamprus murrayi was observed during this study sheltering within CWD and using CWD as elevated sites from which to ambush prey. The low number of captures of the other six reptile species detected during this study precludes any conclusions as to their relationship with CWD.

Table 2. SIMPER test results of the four site composition variables with the highest percent contribution to average squared distance within CWD sites, and within non-CWD sites.

Primary composition variables	Contribution(%)
CWD sites	
Palm fronds	15.16
Logs	12.21
Vine clumps	8.14
Log piles	6.03
Non-CWD sites	
Palm fronds	14.31
Bare soil	8.45
Rocks	5.36
Stags	4.55

The results of the present study are similar to a number of comparable Australian studies that observed that certain forest reptiles have a close association with CWD (Sarre 1998; Brown 2001; Kanowski et al. 2006). The findings of Kanowski et al. (2006) are particularly comparable to the current study results, which also found Eulamprus species to be associated with CWD in rainforest systems.

The lack of significant differences in amphibian captures between CWD and non-CWD sites suggests that frog distribution was not strongly associated with the availability of CWD within the study area. This result conforms to the results of similar overseas studies which found little relationship between frogs and CWD (Aubry 2000; Owens et al. 2008; Davis et al. 2010; Riffell et al. 2011). A study of an Australian floodplain forest by Mac Nally et al. (2001) similarly found no significant difference in frog species richness and densities occurring at sampling sites with and without CWD, although this was attributed to ineffective trapping procedures and low herpetofauna abundance.

Extensive rainfall during the study had a significant effect on the capture outcomes. The severity of the rainfall event which affected the study duration was considerable and very irregular. Reptile and amphibian capture frequencies demonstrated negative and positive correlations respectively with this intensive rainfall event. Previous studies in Australian rainforests have also found herpetofauna activity

Table 3. SIMPER test results of the three site composition variables with the highest percent contribution to average squared distance and dissimilarity between CWD sites and non-CWD sites, with mean abundance at each site type.

Primary Composition variables	Mean abundance (CWD)	Mean abundance (Non-CWD)	Contribution (%)	Dissimilarity/SD
Logs	1.87	0.33	18.03	1.21
Log piles	1.40	0.07	15.94	0.93
Palm fronds	1.20	1.13	10.66	0.78

to be associated with high rainfall, moisture and humidity (Daltry et al. 1998; Brown and Shine 2002), while cooler days, increased humidity, and reduced sunlight reduced reptile activity (Daltry et al. 1998). This appears to have occurred in the present study and is likely to have had a noteworthy effect on the collated results.

Sampling site variation

The dissimilarity in sampling site composition overall was relatively small compared to the dissimilarity between a priori groups when CWD variables were considered. Over 30% of this dissimilarity was attributed to the presence or absence of CWD. This supports the hypothesis that the variation observed between CWD and non-CWD sites in reptile capture frequencies was due to the occurrence of CWD at the sampling sites. Minimal dissimilarity between site composition suggests that amphibians were not strongly associated with the presence of CWD, independent of any influence from other measureable habitat variables. Previous studies (e.g., Mac Nally et al. 2001) have had difficulty in determining whether any relationship exists between CWD occurrence and herpetofauna distribution, independent of other environmental variables.

The measured characteristics of focal CWD did not appear to influence herpetofauna capture rates at any of the CWD sites. Hardness and hollows, in particular, were expected to influence herpetofauna capture frequencies. For example, CWD with an advanced decay rate were expected to yield higher capture rates than harder, less decayed CWD. This expectation was based on previously published studies which observed that variation in CWD hardness, decay state (Siitonen 2001; Bull 2002) and size of CWD influences the composition of the associated species assemblages (Butts and McComb 2000; Bate et al. 2004; Densmore et al. 2004). This variation in the species' use of CWD with different decay characteristics within the study area may have become apparent with increased sampling, which was restricted due to the size of the reserve and the length of the study. Conversely, it may suggest one of two potential relationships. This result could demonstrate that there was no strong association between CWD characteristics and herpetofauna abundance in forests such as Mary Cairncross Scenic Reserve. Alternatively, it may suggest that the drier Australian subtropical forests such as Mary Cairncross Scenic Reserve do not conform to the typical observations of CWD and herpetofauna abundance established in temperate northern hemisphere forests, due to great variation in CWD decay rates.

Management application and considerations

The removal of CWD from forests can have significant impacts on biodiversity (Huston 1996). Furthermore, the reduction or removal of biological legacies through CWD alteration has extensive implications for the biota that depend on them (Lindenmayer and Noss 2006). Removal of CWD should not be a management concern within most Australian State or Commonwealth administered conservation lands. However, in areas managed for timber extraction and areas administered by local authorities or private entities, the removal of CWD for land management could impact environments in ways beyond those caused by the logging of living trees (Lindenmayer 2009). Previous studies on CWD removal have quantified measures to be taken for the conservation of biodiversity in forests (Lindenmayer and Noss 2006; Lindenmayer et al. 2006; Lindenmayer 2009), including the retention of structural complexity components such as CWD (Lindenmayer et al. 2006), particularly in nature reserves and old growth forests (Lindenmayer and Noss 2006). The retention of CWD in forests such as Mary Cairncross Scenic Reserve will prevent habitat loss, both of residing herpetofauna and residing saproxylic invertebrates, an important food source for a range of forest herpetofauna (Whiles and Grubaugh 1996). Similarly, retaining CWD may mitigate the effects of disturbance (Franklin et al. 2000; Patrick et al. 2006) and will ensure the retention of habitat vital to herpetofauna population persistence in times of disturbance or drought.

The current study, which focussed on terrestrial herpetofauna, suggests that in the study area, and potentially other subtropical rainforests, the removal of CWD could be detrimental to herpetofauna such as E. murrayi. To clearly identify the relationship between herpetofauna and CWD within the reserve, a manipulative study could be considered to test the impacts of altering CWD regimes. However, this has been previously unsuccessful at provoking variation in herpetofauna populations (Greenberg 2001; Mac Nally et al. 2001; McCay et al. 2002a, 2002b). Alternatively, expanding the sampling coverage and sampling throughout annual seasonal variation may lessen the influence of rainfall. The management application of the study at present can be applied effectively to the retention of known CWD reliant species such as *E. murrayi*; however, further interpretation and application must be done so conservatively. Expansion of this study as previously mentioned may ensure clear outcomes can be effectively applied to encompass forest herpetofauna communities in management application considerations. Regardless, the outcome of the current research will contribute to further understanding the importance of CWD retention for forest herpetofauna such as *E. murrayi* and contribute to the retention of biodiversity within Australia's valuable subtropical rainforest remnants.

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